# Pintle Injector Study for Liquid Bipropellant Engines

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As a part of advancing the injector technology base in support of the Reusable Launch Vehicle (RLV) engine development and other future rocket engines, an effort of studying a pintle injector for a liquid bipropellant engine system has been performed at Pennsylvania State University (PSU) under a NASA Research Announcement (NRA) cooperative agreement with MSFC. A typical pintle injection element has design characteristics as shown in figure 25. For this study, RP–1 fuel is injected into the combustion chamber from the central post, whereas liquid oxygen (lox) is issued from the outer annulus. Since the design of the central post is crucial for achieving good mixing and combustion, three variations of subject injector configuration, as shown in figure 26, are being examined.

$$\theta = f(TMR, BF)$$

$$TMR = \frac{(Mdot * U)_{RP}}{(Mdot * U)_{Lox}}$$

$$\text{Blockage Factor (BF)} = \frac{\Sigma \text{ Width of Slots}}{\text{Perimeter of Tube}}$$

$$\text{Effective Momentum Ratio (EMR)} = \frac{TMR}{BF}$$

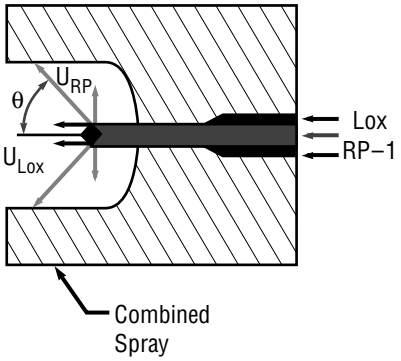


**Figure 25.—Pintle injector design characteristics.**

Cold-flow tests, using water as a propellant simulant, were conducted for the three injectors. The matrix of 3 by 3 images from the test results, as shown in figure 27, were captured using a 35 mm camera. The three images in the first column were taken by positioning the camera directly beneath the pintle tip with flow only ejected through the central post. The first image for injector one shows four liquid sheets emanating from the four horizontal slots, whereas the next two images show 24 liquid jets. The middle and last columns of images were taken by positioning the camera such that the line of sight is perpendicular to the injector axis. The middle column of images for the same central and outer annular flows display the

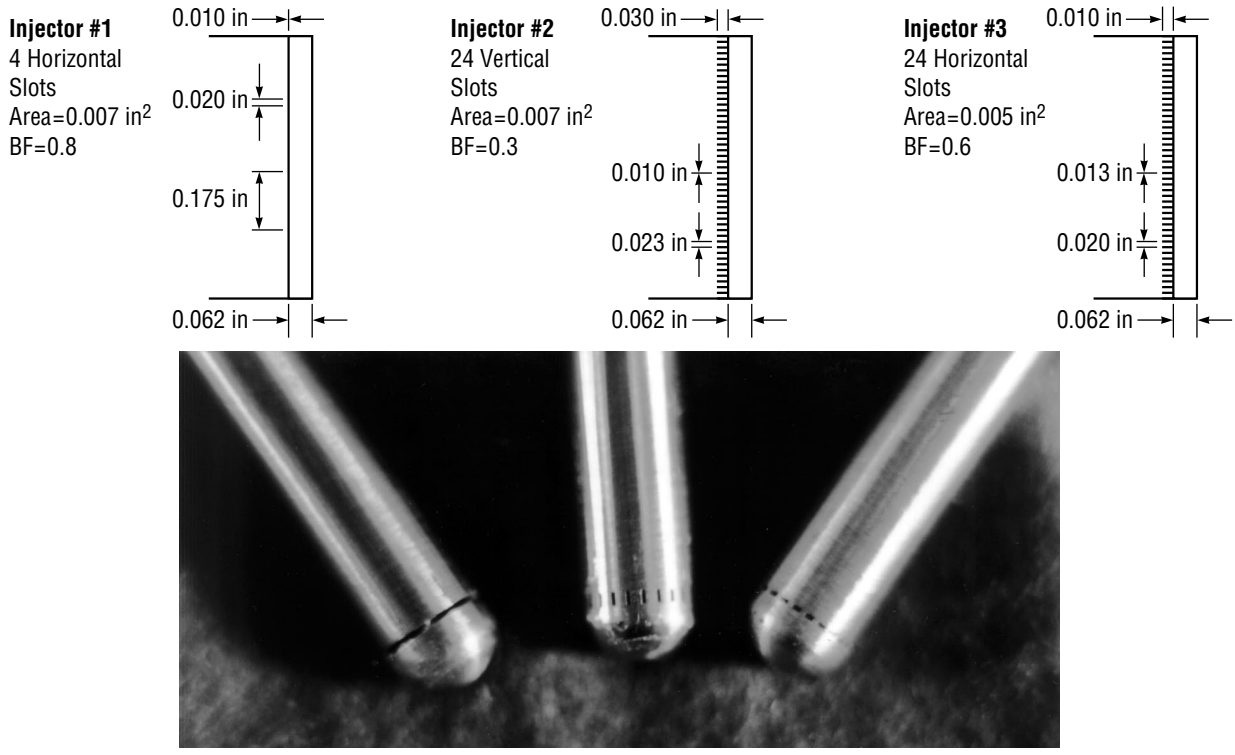


**Figure 26.— Pintle injector tip designs for three injector elements.**

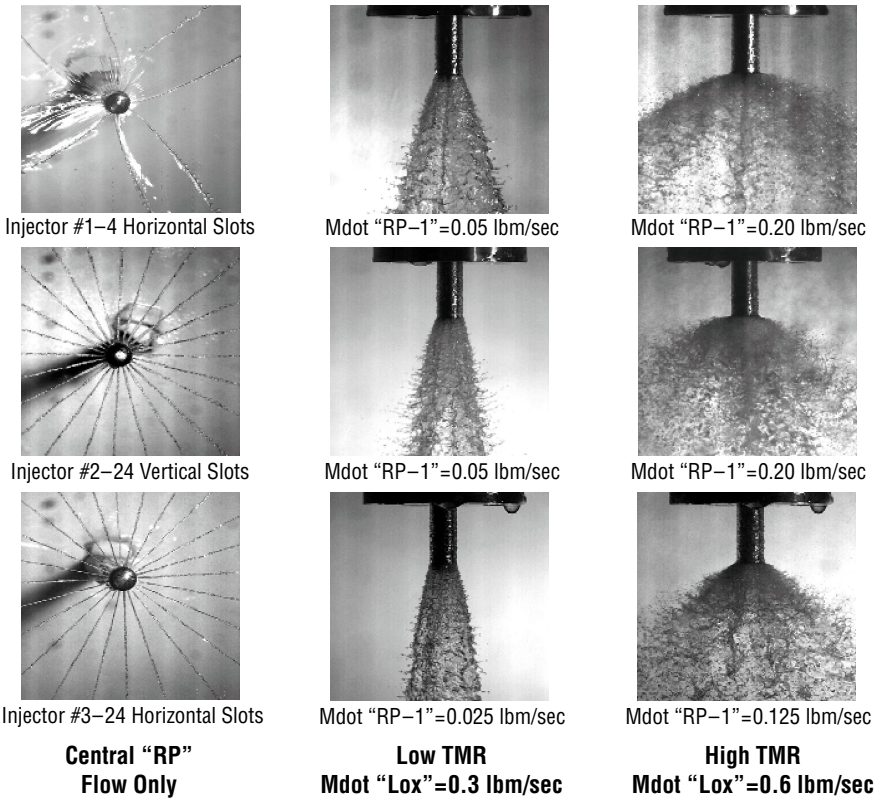


**Figure 27.— Cold flow visualizations for three Pintle injectors.**

effects of the injector geometry on the resulting spray field. The spray cone angle for the first injector, which has 4 horizontal slots, is larger than the one from the 24-slot injectors. Finally, the last column of images shows the spray field for flow conditions where the central to outer annular mass flow rate ratios are higher than that for the images shown in the center column.

The initial series of hot-fire tests for this injector was also conducted with an optically accessible unielement combustor. A panoramic photographic image of a rocket firing is shown in figure 28. The flame luminosity of RP–1/lox combustion is extremely high as evidenced by the light level that passed through a neutral density filter positioned in front of the window.

At present, PSU continues performing parametric hot-fire tests to provide details of the combustion flow field and injector performance characteristics of this injector type.

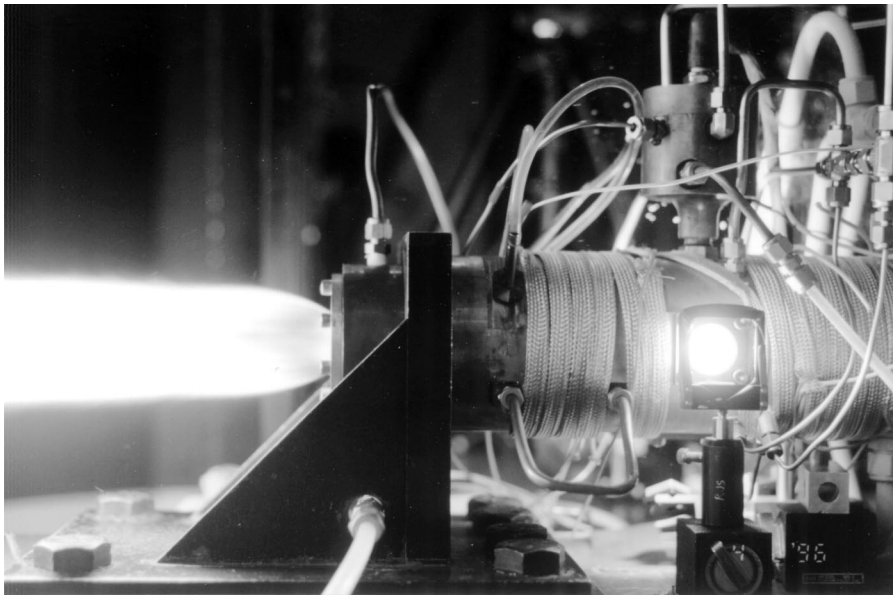

**Figure 28.— Panoramic photograph of RP–1/lox rocket firing for Pintle injector.**

**Sponsor:** Office of Space Access and Technology

**University/Industry Involvement:** Robert J. Santoro and Charles Merkle/The Propulsion Engineering Research Center of the Pennsylvania State University.

**Biographical Sketch:** Huu P. Trinh has worked in the area of liquid rocket engine combustion at MSFC since 1987. He has used computational and analytical models to analyze rocket engine performances. Currently, he monitors a project of providing technologies for main chamber and preburner injectors. The effort is conducted under a PSU NRA cooperative agreement to support the RLV program. In addition, he evaluates injector performance of the Fastrac engine and analyzes proposed Bantam main and gas generator injectors.